Nanocrystalline Co-P-SiC Electrocomposite Coating for Replacement of Hard Chrome

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Report Documentation Page

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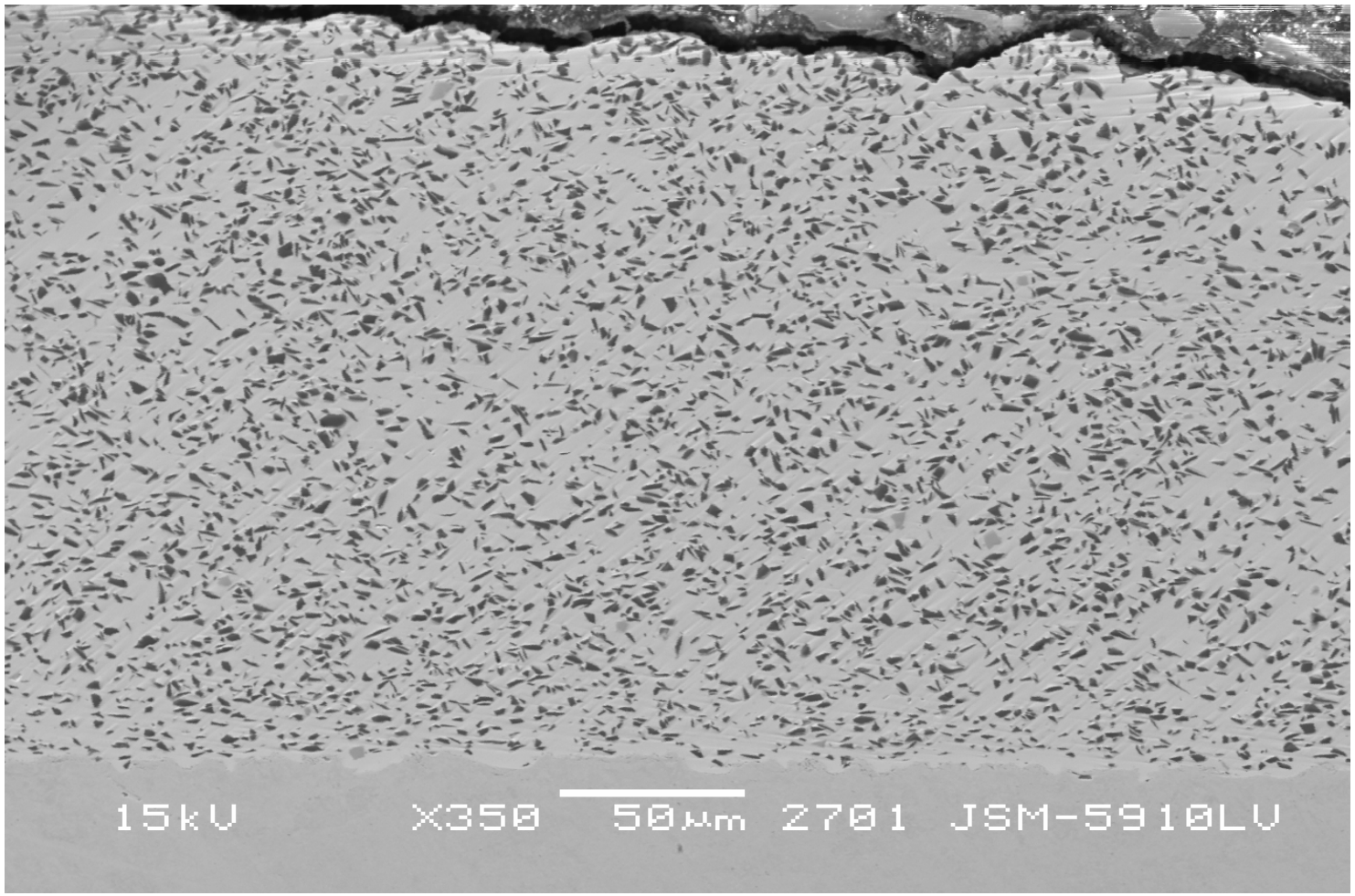
Outline

- Microstructure and X-ray diffraction
- Hardness characteristics
- Process control
- Corrosion resistance
- Wear and friction
- Application status

Microstructure

- Nanocrystaline Co-P matrix with 20-25 vol.% of 2-5μm SiC particles
- SiC particles support contact load; very hard SiC particles provide excellent wear properties.
- Expected to have excellent tribological performance based on those of a similar Ni-SiC electrocomposite coating of U.S.Chrome

Microstructure



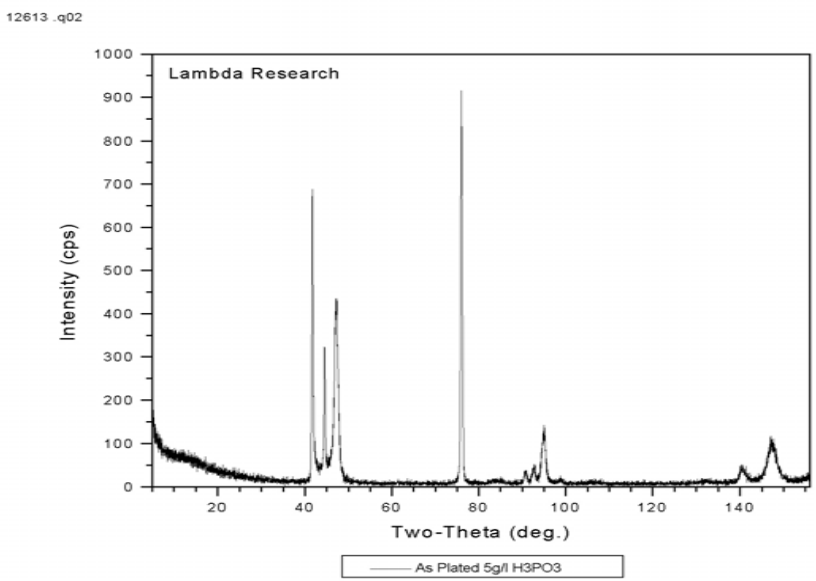
Nanocrystalline Co- P matrix containing 2- 5µm SiC particles ;
No cracks or pits as found in hard chrome

X-ray diffraction results

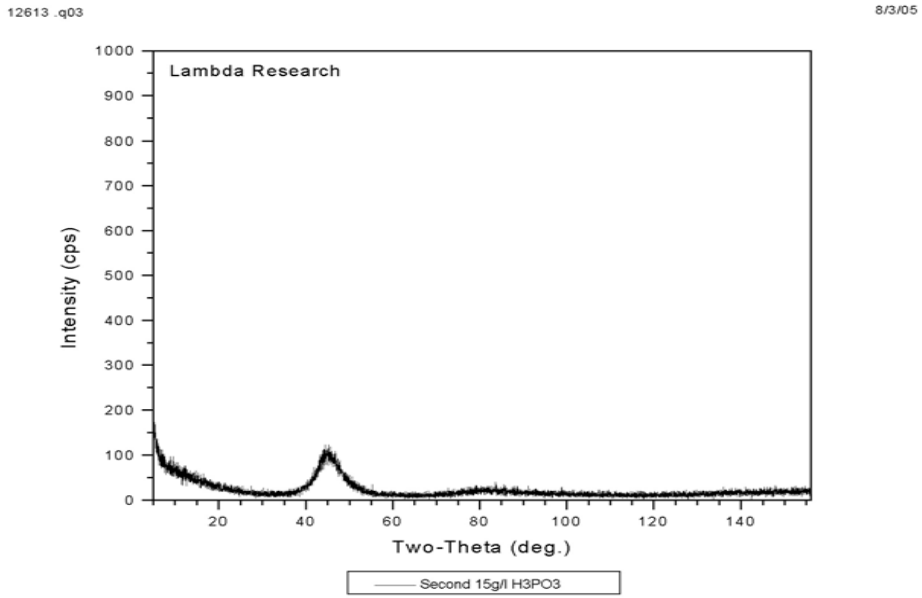
Wt% P of the coating	Coating structure
4.5	Nanocrystalline
5.6	Nanocrystalline
10.5	Amorphous

X-ray diffraction analysis performed by Lambda Technologies, Cincinnati OH.

X-ray diffraction results

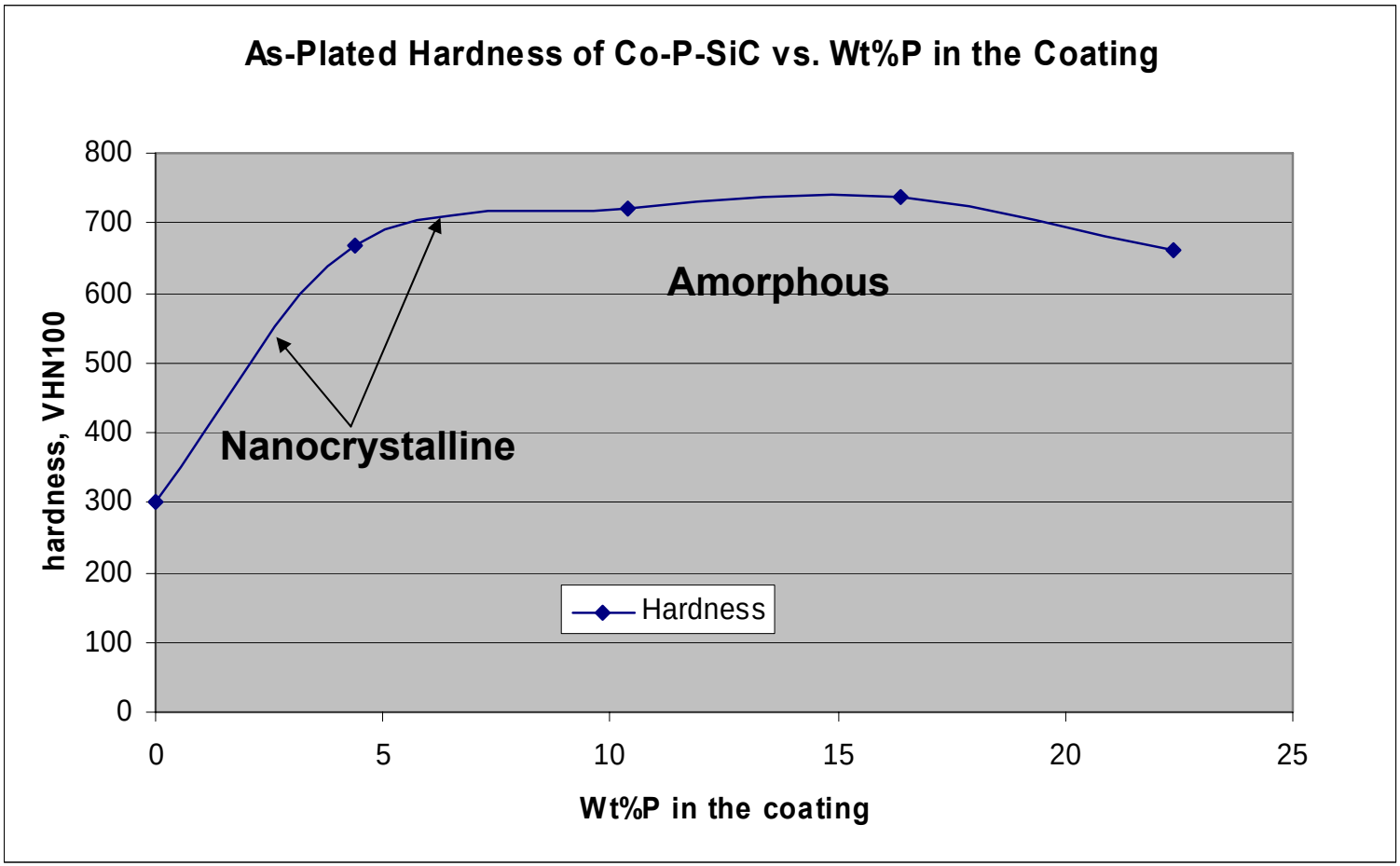


Coating with 4.5 wt.%P
Nanocrystalline
Grain size 48.4 nm



Coating with 10.5 wt%P
Amorphous

Hardness characteristics – As-plated Co-P-SiC



Values of phosphorus content > 8 wt.%P were extrapolated from Measured wt.%P vs. bath Phosphorus content linear regression

Hardness characteristics: 5.6 wt.%P Co-P-SiC and Co-P, heat treated at 400˚C

Coating	As - plated	As heat treated at 400˚C for 1.5hrs	As heat treated at 400˚C for 24 hrs
Co - P	635 VHN_{100}	1000 VHN_{100}	-
Co – P - SiC	653 VHN_{100}	1216 VHN_{100}	1060 VHN_{100}

Increase in hardness resulting from precipitation hardening is appreciably Higher for Co-P-SiC compared to that of Co-P

Hardness characteristics: 5.6 wt.%P Co-P-SiC and Co-P, heat treated at 204˚C

Coating	As - plated	As heat treated at 204˚C for 1.5hrs	As heat treated at 204˚C for 45 hrs
Co - P	635 VHN_{100}	688 VHN_{100}	630
Co – P - SiC	653 VHN_{100}	756 VHN_{100}	756 VHN_{100}

Low temperature heat treatment is necessary for certain alloys. Some hardening is realized even at low temperature. Hardness increase is higher for Co-P-SiC

Comparison with pulse plated Co-P (Integran Tech. Inc. paper, SUR/FIN,2005)

Feature	Co-P-SiC, DC plated 5.6 wt.% P	Co-P Pulse plated 3 – 5.2 wt.%P
Grain size	48 nm	5- 15 nm
As-plated hardness	650 VHN_{100} for 5.6 wt.%P	800 VHN_{100} for 5.2 wt.%P
400˚C HT hardness	1210 VHN_{100} for 5.6 wt.%P	1100 VHN_{100} for 5.2 wt.%P
Variation of as-plated Hardness,3-5.6 wt%P	610 - 650 VHN_{100}	700 - 800 VHN_{100}
Plating rate	0.005 inch/hr at 2ASI	0.002-0.008 inch/hr depending on ASI
Maximum thickness	Plated up to 0.02 inch	Plated up to 0.04 inch

Process Control

- **Conventional DC plating process; Typical plating rate 0.0025 inch/hr; Can be plated with both consumable and non consumable anodes (Platinized Ti, graphite,..)**

- **Maximium thickness plated so far: 0.01 – 0.02 inch**

- **Nanocrystalline structure and SiC particle incorporation are controlled by key parameters.**

- **Key parameters, such as phosphorus content of the bath, pH, current density, temperature , and their ranges are optimized by Design of Experiments (DOE)**

Process Control (continued)

- Different analytical methods for Phosphorus content of the bath and coating were evaluated
- Both ICP and colorimetric methods are used.
- Phosphorous content in the coating was analyzed using colorimetric methods and verified/calibrated using ICP methods.
- Bath phosphorus content is controlled by additions to the bath based on chemistry depletion as a function of Amp.hr used, verified by colorimetric methods.

Corrosion Resistance – ASTM B117

- **0.001” – 0.002” thick 3” x 6” “Q” Panels have exceeded 200 hrs of neutral salt fog exposure with no evidence of red rust.**
- **Panels will continue in cabinet until failure, red rust, appears.**
- **Chromium performs poorly for corrosion resistance due to cracking/stresses.**

In Progress…

- Pin-on-disc wear and friction test
- Embrittlement test (ASTM-F519)
- Further grinding / honing evaluations

Preliminary comparison with hard chrome

Feature	Nanocrystalline Co-P-SiC	Hard chrome
Plating rate	Up to 0.005” per hr (0.0025”/hr typical)	Up to 0.0016” per hr (0.001”/hr typical)
Thickness	Plated up to 0.02”	Typically < 0.02”
As-plated Condition	Crack free	microcracked
Microstructure	48 nm grains with 2-5μm SiC particles	Normal grain size, >1000nm
Power	DC	DC

Preliminary comparison with hard chrome (continued)

Feature	Nanocrystalline Co-P-SiC	Hard chrome
As-plated hardness As HT at 200˚C As HT at 400˚C	650 VHN_{100} 750 VHN_{100} 1200 VHN_{100}	800 -1200 VHN_{100} - -
Thermal stability	400˚C	400˚C
Bend ductility, 0.003” thick, 90˚bend	A few fine cracks at the bend	No visible cracks At the bend
Corrosion	Exceeds 200 hr ASTM B-117	24 hr ASTM B-117

Coating Application Evaluation

- **Coating has been successfully plated onto Ti-6-4, Inconel 718, and Steel with a 0.01 inch thick deposit.**
- **Co-P-SiC coating has been successfully ground to an Ra = 6 µinch finish**
- **A number of industrial applications, such as IC engine bore, are being pursued**
- **Part of a detailed test program being conducted by Air Force's Materials Lab at WPAFB**

Summary

- **A nanocrystalline Co-P-SiC electrocomposite coating has been developed using conventional direct current electroplating process**

- **The coating exhibits all the desired characteristics which are either superior or equal to those of hard chrome**